AUTOGENIC-FEEDBACK TRAINING: A COUNTERMEASURE FOR ORTHOSTATIC INTOLERANCE

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NASA has identified cardiovascular deconditioning as a serious biomedical problem associated with long-duration exposure to microgravity in space. High priority has been given to the development of countermeasures for this disorder and the resulting orthostatic intolerance experienced by crewmembers upon their return to the 1-g norm of Earth. The present study was designed to examine the feasibility of training human subjects to control their own cardiovascular responses to gravitational stimulation (i.e., a tilt table). Using an operant conditioning procedure, Autogenic-Feedback Training (AFT), we would determine if subjects could learn to increase their own blood pressure voluntarily.

When operant conditioning is used to train voluntary control of an autonomic response, the process is called "biofeedback". The question that dominated biofeedback research in its earliest years and excited the interest of the scientific community concerned the rules of plasticity for visceral and central nervous system (CNS) function. It was Miller's contention (1969) that visceral and CNS events may be modified by contingent reinforcement (i.e., operant conditioning) in the same way overt behaviors or skeletal responses may be conditioned. Hence, the "same rules" apply for describing the process by which a pilot learns to control eye-hand coordination when learning to fly an aircraft as in the situation where an individual learns voluntary control of his own heart rate or the vasomotor activity of his hands.

The question as to the specific mechanism by which control of an autonomic response may be learned has spawned considerable basic research. When either classical or operant conditioning is used to modify a visceral response, there are a number of different ways that the effect can be produced (Miller & Brucker, 1979). Skeletal responses may produce *mechanical artifact* in the measurement of the visceral response. For instance, contractions of the abdominal muscle may produce pressure changes in the intestine that can be mistaken for intestinal contractions, (Miller, 1977). Skeletal muscles may produce purely *mechanical effects* on visceral processes. Yogis who claim the ability to stop their hearts actually perform valsalva maneuvers, building sufficient thoracic pressure to collapse the veins returning blood to the heart. Although heart sounds and pulse cannot be detected, the electrocardiogram shows that the heart still beats (Anand & Chhina, 1961). Skeletal responses may stimulate a *visceral reflex* such as heart rate and blood pressure increased by isometric contractions (Lynch, Schuri & D'Anna, 1976). Any of these skeletally influenced responses may be learned but they do not indicate learning by the autonomic nervous system.

A series of clinical investigations was initiated on patients with generalized bodily paralysis who suffered from episodic orthostatic intolerance, (Brucker & Ince, 1977; Pickering, et al., 1977). It was hypothesized that if learned control of blood pressure could be demonstrated in these individuals where skeletal influence was not a factor, then the basic research question of visceral plasticity could be examined and the therapeutic benefits of such training could be explored. The results of these studies showed that patients could learn to produce increases in blood pressure ranging from 20 to 70 mm Hg, with the consequence of eliminating their orthostatic intolerance. These studies succeeded in establishing that control of blood pressure can be learned independent of skeletal musculature or changes in respiration. They demonstrated also that training increases specificity of control, eventually eliminating accompanying pulse rate increases. And performance of these patients conformed to the cardinal "rule" of operant conditioning: skill increases with practice.

The implications of these results for developing a potential countermeasure for orthostatic intolerance in cardiovascularly deconditioned crewmembers, are apparent. Paralyzed patients show much greater spontaneous variability in blood pressure than do normotensives, but bedrest studies indicated that normal subjects also tend to exhibit weaker homeostatic control over cardiovascular responses after prolonged inactivity (Sandler & Vernikos, 1986). Rather than attempting to remove the influence of skeletal musculature (as was the goal of the above authors), contraction of muscles by non-paralyzed subjects would be expected to enhance the desired effect of increasing blood pressure. The presence of sympathetic vasomotor innervation in normals should further facilitate peripheral vasoconstriction.

The hypotheses of this study were:

1. Normotensive individuals could learn to increase blood pressure under supine conditions.

2. Control of blood pressure could be produced under conditions of gravitational stimulation.

METHODS

Subjects. Six men and women between the ages of 32 and 42 participated in this study. Subjects were physically fit as determined by medical examination and their participation was voluntary.

Apparatus. A primary criterion for this type of training, is that the individual must be presented with on-going information about his own physiological responses in real-time (e.g., displaying heart rate on a digital panel meter). For the present study, a computer-controlled blood pressure monitoring system was developed, which provided continuous "feedback" of both systolic and diastolic blood pressure on every beat of the heart (Tursky, Shapiro & Schwartz, 1972). This non-invasive system used two blood pressure cuffs, mounted over the brachial arteries of the left and right arms.

The cuff measuring systolic blood pressure was initially inflated to just above systoli. Using the R wave of an electrocardiogram to initiate a timing window, cuff pressure automatically deflated or inflated, in 3 mm Hg increments, as the system "searched" for the presence of Karotkoff sounds detected by a crystal microphone beneath the cuff. If the K-sound was present, cuff pressure was increased on the subsequent heart beat; if absent, cuff pressure was decreased. In this manner, it was possible to track blood pressure on each heart beat. The tracking cuff was inflated for a period of one-minute at a time, alternating with deflation during 30-second "rest periods" to allow normal circulation to resume. The measurement of diastolic blood pressure (on the other arm) reversed this process.

Procedure. Each subject was given 4 to 9 training sessions (15-30 minutes in duration). Baseline recordings were taken of resting supine heart rate and blood pressure and changes in these variables resulting from passive head-up tilt of 45 degrees. Subjects were then provided with information on their own blood pressure in the form of a computer screen numerical display which updated on each heart beat and/or two mercury columns showing systolic and diastolic pressure, respectively. Under supine conditions, subjects were instructed to increase their own blood pressure, and given an opportunity to practice control. When blood pressure increases were demonstrated under supine conditions, subjects were again tilted to 45 degrees (head up) and asked to increase their blood pressure.

RESULTS

Under baseline supine and passive tilt conditions, the blood pressure tracking system was able to reliably measure blood pressure and heart rate on a beat-to beat basis. All subjects showed, in response to passive tilt, an initial drop in systolic pressure, increase in diastolic pressure and a corresponding rise in pulse rate (Figure 1).

During supine training sessions, all subjects demonstrated learned increases in blood pressure ranging from 20 to 50 mm Hg (Figures 2-3). In all of these subjects, this same degree of blood pressure control was also possible under subsequent head-up tilt conditions. Figure 4 shows the data of one of these subjects. The left side of this graph shows one minute of resting blood pressure and heart rate, followed by a voluntary increase of blood pressure during tilt of maximally 50 mm Hg. Heart rate showed an initial increase from 64 to 96 beats per minute, with a subsequent fall in pulse rate without changing blood pressure levels.

CONCLUSIONS

This study demonstrates that learned control of blood pressure by normotensive individuals is possible. This skill could be a valuable adjunct to other counter-measures (e.g., inflight fluid loading and exposure to Lower Body Negative Pressure, LBNP). A bed-rest study could be conducted which would best evaluate the effectiveness of this procedure, alone and in combination with other treatments, as a countermeasure for orthostatic intolerance in cardiovascularly deconditioned people. The results of that study would determine the value of developing AFT for preflight and in-flight procedures for treatment of orthostatic intolerance in aerospace crews. For example, blood pressure conditioning sessions could be incorporated into the spacelab exercise facility.

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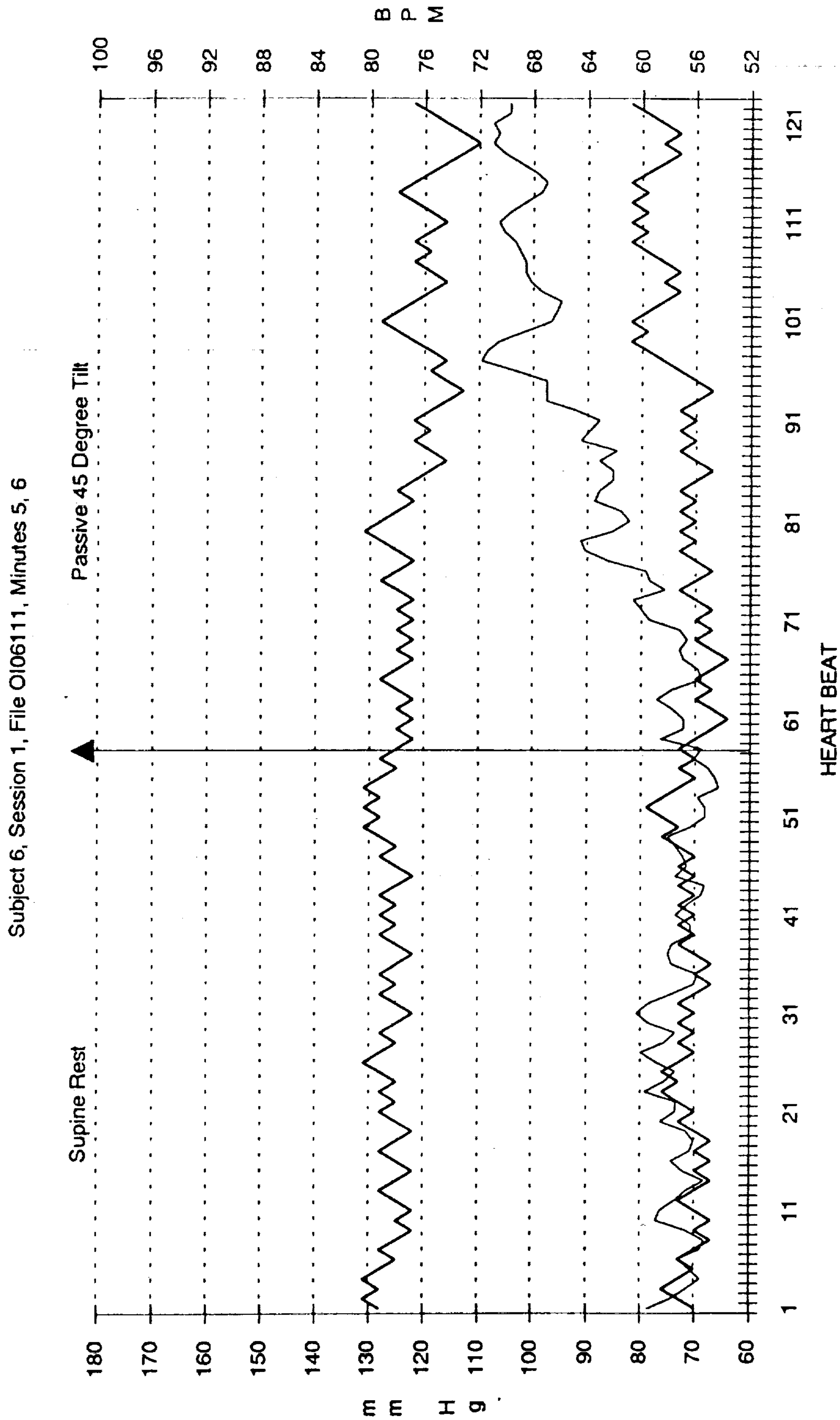
FIGURE CAPTIONS:

Figure 1:The data of a representative subject during supine baseline and passive tilt conditions. The upper dark line represents systolic blood pressure, the lower dark line is diastolic blood pressure (read axis on left, mm Hg). The thin line is heart rate (read axis on right, BPM). Note: all subsequent graphs are read similarly.

Figure 2: A two minute sample of one subject's data while practicing blood pressure increases under supine conditions.

Figure 3: A two minute sample of one subject's data while practicing blood pressure increases under supine conditions.

Figure 4: A two minute sample of one subject's data while practicing blood pressure increases under head-up tilt of 45 degrees.



Subject 6, Session 1, File OI06111, Minutes 5, 6
Supine Rest
Passive 45 Degree Tilt
mmHg
180
170
160
150
140
130
120
110
100
90
80
70
60
BPM
100
96
92
88
84
80
76
72
68
64
60
56
52
1
11
21
31
41
51
61
71
81
91
101
111
121
HEART BEAT

FIG. 1

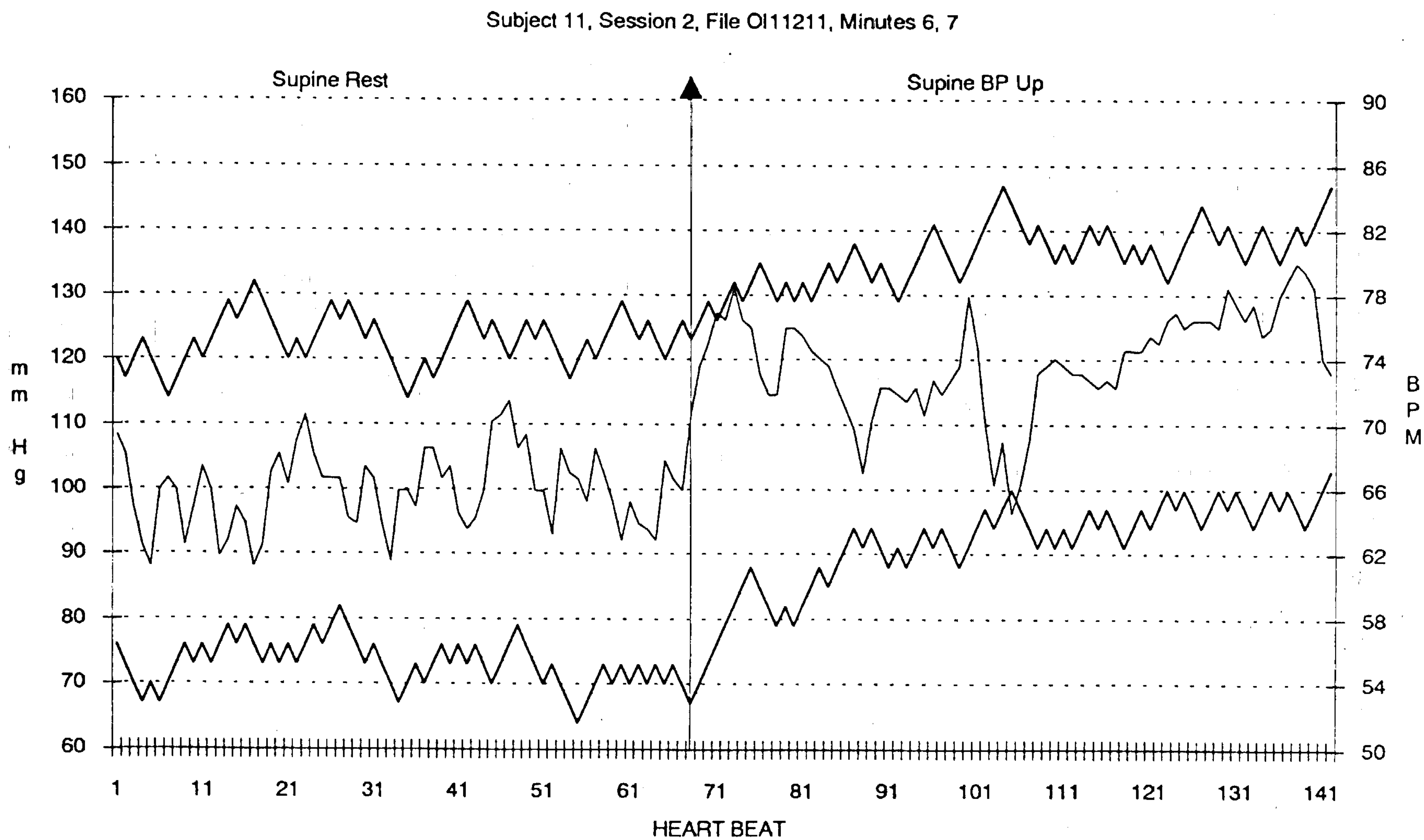

Subject 11, Session 2, File OI11211, Minutes 6, 7
Supine Rest
Supine BP Up
mm Hg
BPM
HEART BEAT
160
150
140
130
120
110
100
90
80
70
60
90
86
82
78
74
70
66
62
58
54
50
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141

FIG. 2

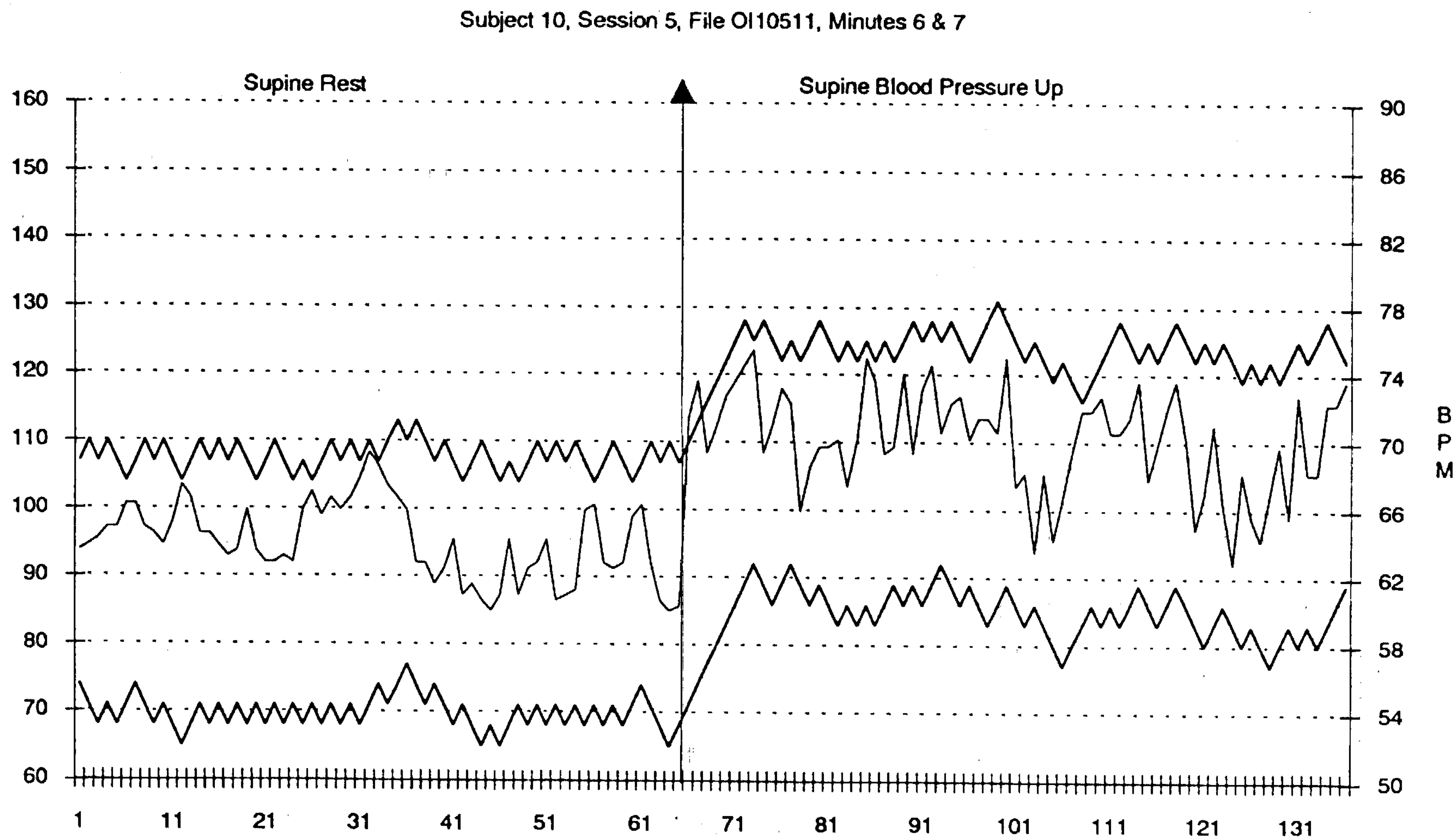

Subject 10, Session 5, File OI10511, Minutes 6 & 7
Supine Rest
Supine Blood Pressure Up
160
150
140
130
120
110
100
90
80
70
60
mmHg
90
86
82
78
74
70
66
62
58
54
50
BPM
1
11
21
31
41
51
61
71
81
91
101
111
121
131
HEART BEAT

FIG. 3

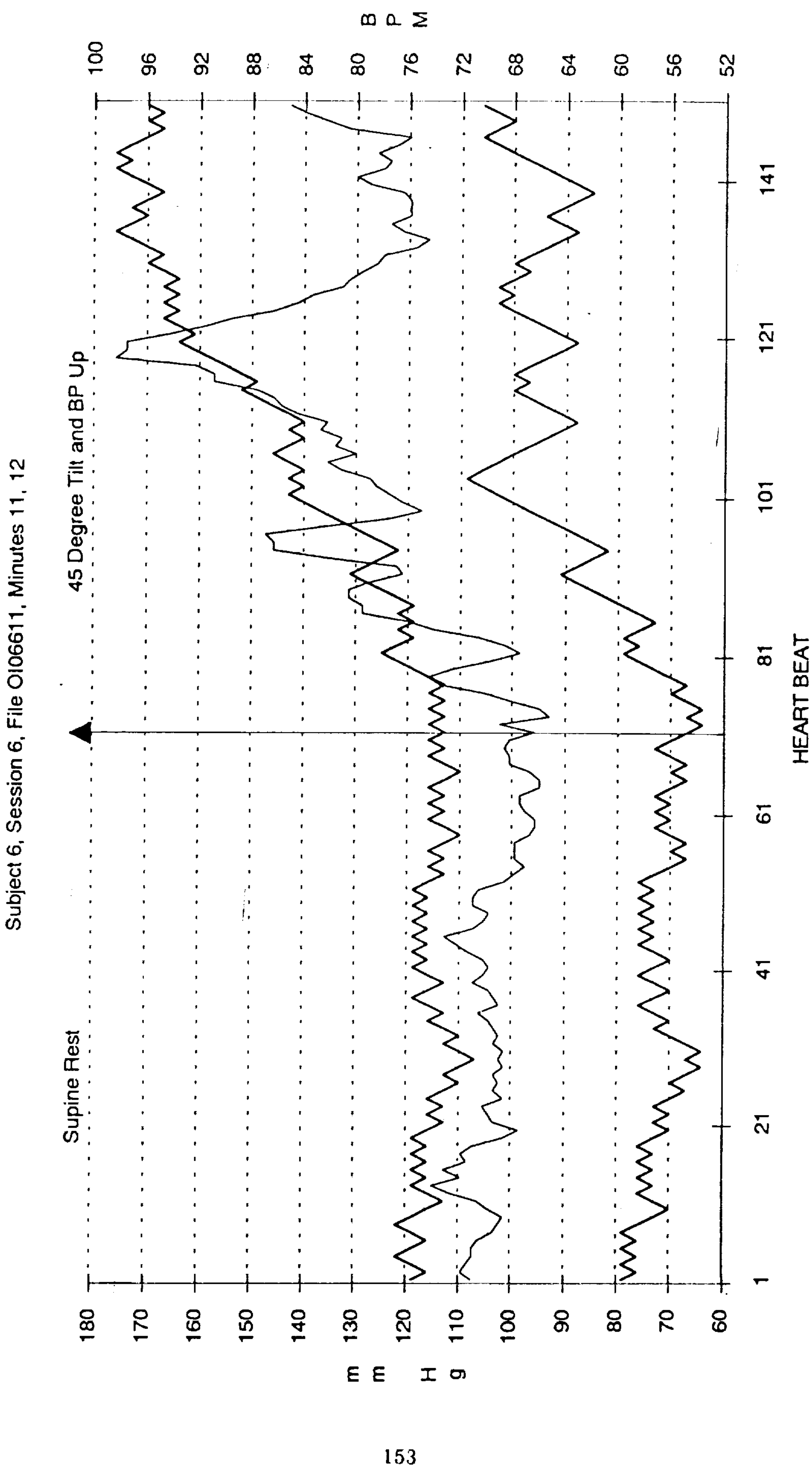

Subject 6, Session 6, File OI06611, Minutes 11, 12
Supine Rest
45 Degree Tilt and BP Up
mmHg
180
170
160
150
140
130
120
110
100
90
80
70
60
BPM
100
96
92
88
84
80
76
72
68
64
60
56
52
1
21
41
61
81
101
121
141
HEART BEAT

FIG. 4